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WHEN THE MODIFICATIONS MADE TO THE FOGGARA DISTURB THE ENVIRONMENT

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ABSTRACT

This paper examines, for the first time, the consequences of modifications to the Foggara system on the environment. During our work and research missions carried out in the oases of Touat, Gourara and Tidikelt during the last 20 years (period 2000–2020), we have observed new practices operated by land owners on the Foggara, namely changes introduced in different parts of the Foggara with the aim of improving the flow of the Foggara. Two materials, PVC and Cement, were introduced in the oases of Touat, Gourara and Tidikelt. The earthen Souagui were replaced by PVC and PEHD pipes and the earthen Madjens were changed to cement Madjens. These modifications turned out to be dramatic for the aesthetics and hydraulics of the Foggara. Such interferences may cause the disappearance of this ancestral heritage, and will have negative repercussions on tourism in the region.

Keywords: Cement modification; Environment; Foggara; Oasis; PVC pipe.

1 INTRODUCTION

The Foggara is a thousand-year-old hydraulic system based on collecting and sharing groundwater through a simple underground gallery [1–4]. The Foggara has contributed to the development of hundreds of oases in the Algerian Sahara. Twenty centuries passed, the Foggara still operates despite competition from new collection techniques; this is the miracle of the Foggara. Native to ancient Iran (Persia) [5, 6], Foggara has been exported to more than 50 countries around the world [4, 7]. However, today, the number of Foggara in service has declined significantly around the world due to competition with modern techniques (drilling and motor pumps). Today, the Foggara is operational in several countries on the planet only. These countries are Iran, Algeria, Morocco, Afghanistan, Pakistan, China and the Sultanate of Oman [3, 8]. Called Foggara in Algeria, Qanat in Iran, Khettara in Morocco, Karez in Afghanistan, China, Pakistan and Falaj in the Sultanate of Oman, the draining galleries have contributed to the development of oasis agriculture in these arid regions for more than 20 centuries. It is in Iran that the Qanat is the most protected since the number of Qanat in service exceeds the threshold of 3000. The Karez have been excavated in China for more than 20 centuries [9]. More than 1780 Karez were inventoried in 2003 with a total length of the gallery equal to 5270 km [10]. Only 615 Karez are in service today, constituting a loss of 20 to 30 Karez per year [11]. In Afghanistan, more than 5,887 Karez have been recorded, only 611 are currently in operation [12]. In Pakistan, 1053 Karez are in operation and 270 in shutdown, but which can be maintained [13]. It was in Iran that the Qanat was invented. In 1966, the number of Qanat in service reached the value of 38,000 with a total length of the gallery approaching the figure of 350,000 km. However, in 1998, this number dropped to 20,000 and to the value of 18,000 during the past ten years [14]. In Morocco and more exactly in the region of Marrakech, at the beginning of the 1970s, there were 567 Khettaras with a total length of the gallery equal to 900 km, of which 500 were in service (flow 5 m^3/s) [15]. In Sultanate Oman, 3000 Aflaj in operation were recorded in 2006 [16].

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2 STUDY REGION AND INVESTIGATION

This study is the culmination of extensive fieldwork. During more than 20 years (period 2000–2020) of trips through the oases of Touat, Gourara and Tidikelt, we visited and studied several Foggara. These humid regions located at the heart of a vast dry environment are located between 1,200 and 1,400 km southwest of Algiers (Fig. 1).

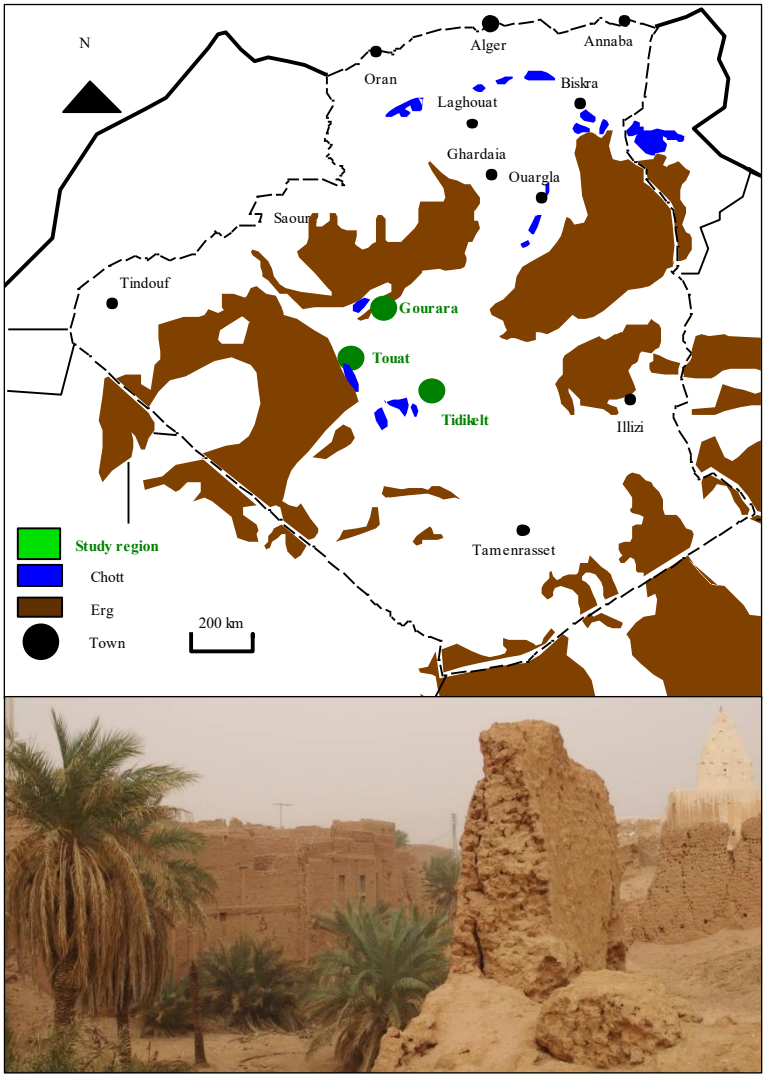

Figure 1. *Geographical location of the study regions (Gourara, Touat and Tidikelt) (Photo: Remini, 2013)*

During this long period of 20 years, we have followed the evolution of these Foggara. Indeed, over the years we have observed a very worrying phenomenon which is evolving rapidly in the oases of Touat, Gourara and Tidikelt. These are PVC pipes and solar powered pumps. For the Foggara in service, each time farmers replace a Seguia section with a PVC pipe, the Foggara deteriorates. Regarding the degraded Foggara, the farmers drill a borehole next to the Foggara which consists of pumping underground water by solar energy and then channelling it into the Foggara distribution network. These new modifications to the Foggara have accelerated in recent years, which may cause the disappearance of this ancestral heritage in the short term. To slow down the evolution of these modifications, we must sensitize farmers and Foggara owners to stop these practices and adopt rehabilitation operations carried out by specialized consulting firms.

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3 RESULTS AND DISCUSSION

The Foggara is an ancestral hydraulic system consisting of an underground gallery to drain water from the aquifer to the surface of the soil [17]. Thanks to the network of Souagui, Kasriates and Madjens, water reaches the garden of each owner [18] (Fig. 2). Composed of two parts, the Foggara ensures the collection, transport and sharing of water between shareholders [19] (Fig. 3). Intended to drain and transport water from the aquifer to the ground surface, the upstream part consists of an underground gallery equipped with a hundred aeration shafts [3]. The downstream part which represents the distribution network which begins from the main Kasria (beginning of water sharing) until the water arrives by Souagui to be stored in the last Madjen before the irrigation of the Guemoun (Figs. 4 and 5). The Foggara is a hydraulic system that supplies the Ksar with drinking water and irrigates the gardens [2] (Figs. 6 and 7). Only the supply of drinking water is provided free of charge, on the other hand, the irrigation flow is ensured according to the contribution of each co-owner in the maintenance of the Foggara.

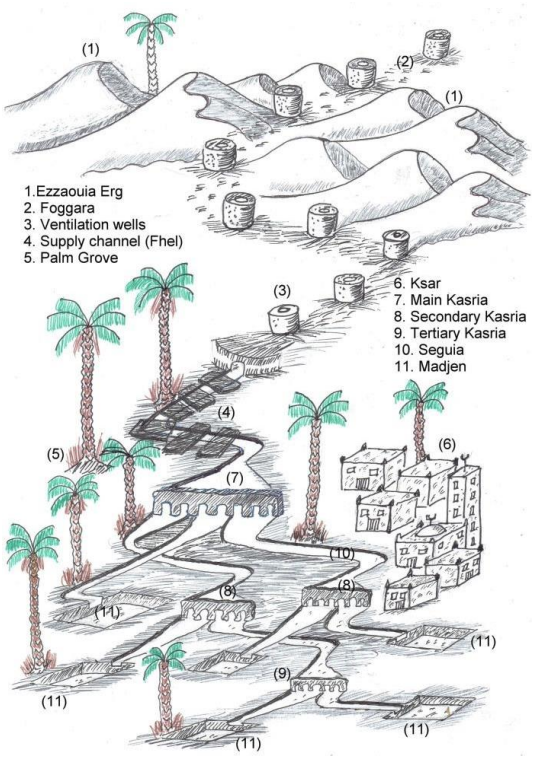

Figure 2. *Synoptic diagram of a Foggara in the In Ghar oases in the Tidikelt region (Diagram executed by Remini, 2021)*

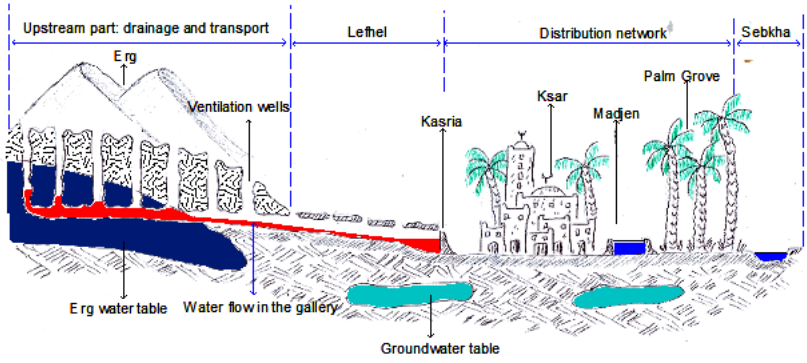

Figure 3. *Block diagram of an Erg Foggara in the In Ghar oases (Diagram executed by Remini, 2021)*

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***Figure 4**. Secondary Kasria of an In Ghar Foggara in the Tidikelt region (Photo: Ghachi and Remini, 2013)*

***Figure 5**. Madjen and secondary Kasria of an In Ghar Foggara in the Tidikelt region (Photo: Ghachi and Remini, 2013)*

***Figure 6**. Water from the Foggara is free in the Ksar of an oasis of In Ghar in the Tidikelt region (Photo: Ghachi and Remini, 2013)*

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Figure 7. *Irrigation water in the gardens of the Irsan oasis (Tidikelt region) (Photo: Ghachi and Remini, 2013)*

The success of the Foggara is justified by the transfer of know-how in more than 50 countries of the planet [7]. In addition, the Foggara has operated for more than 20 centuries in the oases of Touat, Gourara and Tidikelt, despite competition from new irrigation techniques [2]. The Foggara, this ingenious system is not limited to irrigating the gardens and supplying the Ksar with drinking water, but rather, it is a structure that protects the environment of the oasis.

The Foggara was designed to carry very good quality water. In fact, the water captured from the depth of the aquifer travels through an underground gallery of tens of kilometres in the middle of several types of rocks. Once on the ground, water is distributed free of charge to the local population for domestic needs. In return, this water of exceptional quality is shared between the co-owners who have contributed to the digging and maintenance of the Foggara. Each share of water is related to the contribution of each shareholder [18]. Irrigation of the Guemoun with Foggara water can only provide high quality products.

In the oases of Touat, Gourara and Tidikelt, the water from the Foggara intended for irrigation is well optimized; there is neither a surplus nor a deficit of water. Regarding the quality of the Foggara in addition to being water extracted from the bottom of several layers of the soil, it flows over ten kilometres of galleries while marrying different types of rocks. When it reaches the surface of the soil, the water is rich in several nutrients which are certainly beneficial for the plant. This is verified by the good quality of agricultural products irrigated by water from the Foggara.

Unfortunately, over the past 30 years, changes have been made to the Foggara. Whether at the gallery level or at the level of the distribution network, farmers made anarchic repairs to the Foggara with the sole aim of seeing the water flow into the garden. Table 1 summarizes the types of modifications made to the Foggara of the Touat, Gourara and Tidikelt regions. On the gallery, changes have been made to the transport part of the gallery and to the ventilation shafts (Fig. 8). In order to reduce infiltration in the "Transport" part and consequently increase the flow of the Foggara, PVC or cement pipes have been introduced into the gallery. However, such a delicate and costly operation for farmers, its profitability remains very low since the variation in flow rate is low. In addition, the absence of a route of a hundred meters through different types of rocks, the quality of the water drained by the pipes is not as before. The location of these PVC pipes requires excavation in the gallery several meters deep in order to obtain the best possible bed to avoid the problem of laying the pipes.

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Figure 8. *The gallery of the transport part has been replaced by PVC pipes (Photo: Abidi Nouh, 2010)*

Another development which has gained momentum in several oases and which affects the aesthetics of the Foggara itself and its environment is how the ventilation shafts of the Foggara crossing a town were 'rehabilitated' in an uncontrolled manner. Copings of different shapes (square and circular section) made of concrete blocks, bricks and stones were observed during our field missions (Fig. 9). Virtually no rehabilitation operation has been carried out using materials appropriate to the initial shape.

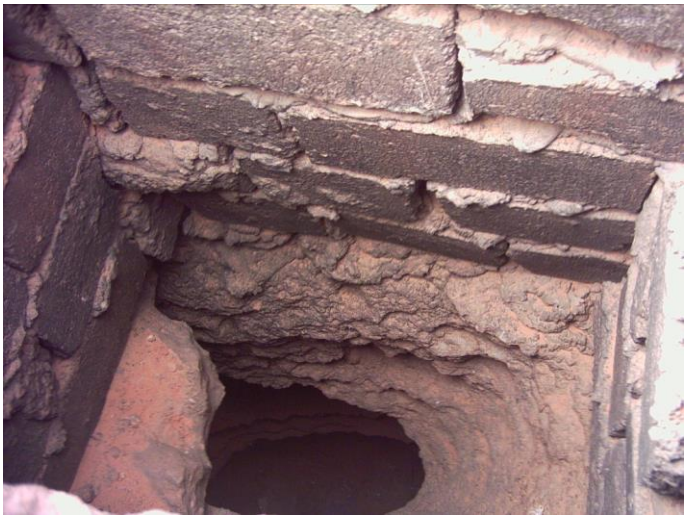

Figure 9. *A square cinder block coping in a well ventilation of a Foggara in Timimoun (Photo: Remini, 2008)*

It shows that the distribution networks in the palm groves have been changed in all parts. Whether it is the Souagui, Kasriates and Madjen, they should have been left in the initial state, i.e. carried out in the ground. The infiltrations carried out at the level of these structures (Souagui, Kasriates and Madjens) are useful and beneficial for the palms and plants existing on the periphery of these structures which benefit from permanent irrigation. In recent years, we have seen the introduction of two new materials in the oases of Touat, Gourara and Tidikelt:

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PVC and cement. In general, the arrangements were made at the level of the ventilation shafts, the Madjen and the Souagui. In the first stage, the wells underwent modifications in cement and concrete blocks at the level of the copings. On the other hand, the Souagui have been completely modified. Most earthen Souagui have been modified to cement or concrete.

This new situation caused the infiltration to stop and as a result hundreds of palm trees around the Souagui have disappeared. Even the Madjen have not escaped these arrangements. Cement Medjen reduce infiltration, but the peripheral palms which irrigate permanently since their roots are in contact with the infiltrated water, die thirsty for lack of infiltration (Fig. 10).

Figure 10. *Madjen realized in cement in the palm grove of Irsan (Photo: Ghachi and Remini, 2008)*

In the second step, the PVC pipes of different diameters are in great demand by the owners of the Foggara. PVC pipes have taken the place of earthen or cement Seguia (Figs. 11, 12 and 13). Even the Kasria have not escaped this phenomenon, since PVC pipes are connected directly to the Kasria (Fig. 14). This situation is gaining momentum in the oases of Touat, Gourara and Tidikelt. With such a rhythm, in a few years, such interferences with the Foggara will dominate in all the oases.

Figure 11. *Pipes instead of Souagui in the palm grove of Touat, Gourara and Tidikelt (Photo: Ghachi and Remini, 2013)*

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Figure 12. *Foggara de Tafza: Replacing the Souagui by HDPE pipes (Photo: Ghachi and Remini, 2013)*

Figure 13. *PVC pipes of different diameters occupy the gardens (Photo: Ghachi and Remini, 2013)*

Figure 14. *Even the Kasriates have been modified by the addition of PVC pipes (Photo: Ghachi and Remini, 2013)*

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PVC has given a poor aesthetic image to the Foggara and its environment, which may even have consequences for the tourism sector in the region (Fig. 15). In addition, the open air flows in the Souagui several kilometres long give off strong evaporation in summer and consequently a humid micro climate emerges inside the palm grove. Between the outside of the oasis and the inside of the palm grove, there is a temperature difference that can exceed 15° C.

Figure 15. *In the oasis of Timimoun, a kasria unrecognizable due to PVC (Photo: Remini, 2008)*

We have also observed a new phenomenon; the population uses the Foggara air vents as public rubbish bins (Fig. 16). An original case was seen in some oases of Touat which corresponds to the equipment of a Foggara by a motor-pump well using solar energy in order to improve its flow. Reaching this stage, the Foggara no longer plays its role, except that the owners in this case take advantage of the Foggara distribution network to bring water from the well to the farmers' gardens.

Figure 16. *The ventilation shafts used in the towns of Touat, Gourara and Tidikelt regions as public trash cans (Photo: Ghachi and Remini, 2013)*

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Table 1. *Summary of the uncontrolled modifications made to the Foggara*

Place of modification	Type of modification	Consequences
Gallery of the Foggara	• Reinforcement of the gallery with PVC or HDPE pipes	• Rapid flow and variation of the Foggara flow • The water loses its quality • Less ventilation • Absence of infiltration
Well of the Foggara	• Reinforcement of the wells with bricks and concrete blocks.	• Deteriorated aesthetics of the Foggara
Lefhel	• Replacement of the earthen channel with a concrete channel covered by concrete slabs.	• Quick flow • Absence of infiltration
Kasria	• New concrete Kasriats • Replacement of the openings of the kasria by sections of PVC pipes	• Aesthetic problems • Problems of flow measurements
Seguia	• Replacement of earth channels with pipes of different diameters in PVC or HDPE	• No evaporation and therefore there will be less humidity in the palm grove
Madjen	• Replacement of the earthen Madjen by a concrete or cement Madjen	• Lack of infiltration and therefore there will be no more palm trees on the outskirts of the Madjen
At the periphery of the Foggara	• Reinforcement of the Foggara by a motor-pump well with solar energy	• It is no longer a Foggara, but a borehole that uses the Foggara network to fill the Madjen

4 CONCLUSION

As we mentioned, the Foggara has played a big role in the development of the oases of the regions of Touat, Gourara and Tidikelt. After 20 centuries of operation, this hydraulic heritage is in danger, it risks disappearing in the near future if maintenance and rehabilitation measures are not taken urgently. It should be noted that hundreds of Foggara are already under the rubble and sand dunes. Other Foggara are suffering from landslides and degradation as a result of the vagaries of the weather. Farmers try to keep the Foggara "alive" by making changes in different parts of the system regardless of the consequences for the environment of the oasis and the aesthetics of the Foggara itself. The rehabilitation of the Foggara must be carried out using the same materials used initially. Unfortunately, what is happening today in the oases and quite the opposite especially with the addition of PVC and HDPE material which is gaining momentum in all the oases in Foggara. The earthen Seguias have been renovated and modified, but with PVC and HDPE pipes. Earthen Madjen have been replaced by cement Madjen. The image of today's Foggara has simply been damaged by the established PVC and cement modifications to the Foggara.

NOTES

foggara	horizontal well
guemoun	garden
ksar	city of farmers
ksours	plural of *ksar*
kasria	parter
kasriates	plural of *kasria*
madjen	water storage basin
lefhel	earthen canal covered with flat stones connecting the exit of the gallery to the main *kasria*
seguia	earthen canal
souagui	plural of *seguia*

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